Objectives

Erosion and Sedimentation:
1. Sediment Properties and Fall Velocity;
2. Flow Properties;
3. Incipient Motion;
4. Riprap Design;
5. Bed Load and Suspended Load;

1. Sediment Properties and Fall Velocity
Fall Velocity

\[ \begin{align*}
\bar{v} &= \frac{2(G-1)d^2}{18} & \text{Stokes Law valid for silts & clays} \\
\bar{v} &= \frac{4 g(G-1)d^2}{\sqrt{3}} C_p & \text{valid for gravels, cobbles & boulders} \\
\bar{v} &= \frac{d_p}{\varepsilon} \left[ 1 + \left( \frac{d_p}{2b} \right)^{0.5} \right]^{-1} \\
\text{dimensionless particle diameter} \\
\varepsilon &= \frac{(G-1)\varepsilon^2}{\nu} \\
\end{align*} \]

2. Flow Properties

Logarithmic Velocity Profile
Open Channel Flow

- Pressure Distribution
  \[ \phi = \frac{1}{2} \rho g h^2 \]

- Shear Stress
  \[ \tau = \rho g h \bar{u} \]

- Shear Velocity
  \[ u_s = \sqrt{ghS_f} = \sqrt{9.81 \frac{m}{s^2}} \times 9.9 \times 0.001312 \]
  \[ u_s = 0.113 \frac{m}{s} \]

Example - Shear Velocity

Resistance to Flow

- Manning-Strickler
  \[ R = 5 \left( \frac{m}{g} \right)^{1/6} \sqrt{g h S_f} \]
  \[ n = 0.064 \frac{d_{eq}^{5/3}}{d_{po}^{2/3}} \] with \( d_{eq} \) in m
3. Incipient Motion

Incipient Motion

Angle of Repose

Effects of Angularity

Motion occurs when the center of gravity (G), is inline with the point of contact (C).
Angle of Repose
Granular Material

Shields Parameter
• Ratio of Hydrodynamic Forces to Submerged Weight

Beginning of Motion
• Critical Shields Parameter ($\tau_c$)
  – beginning of motion ($\tau = \tau_c$)
Critical Shear Stress

4. Riprap Design
Velocity Method

\[ V_c = K_c \sqrt{2(G-1)gd_s} \]

\[ K_c = \log \left( \frac{4h}{d_s} \right) \tan \phi \]

**Riprap Design**

- Well graded riprap scours less than uniform size riprap due to the process of armoring
- Suggested Riprap gradation from USACE is shown to the right
- Riprap with poor gradation may be used, but a "filter" layer is required

**Gradation of Riprap**

<table>
<thead>
<tr>
<th>Percent by Weight</th>
<th>Fine Diameter ((=d_s))</th>
<th>Screen Diameter ((=d_{50}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.55</td>
<td>0.28</td>
</tr>
<tr>
<td>10</td>
<td>0.33</td>
<td>0.63</td>
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<td>1.50</td>
</tr>
<tr>
<td>90</td>
<td>1.80</td>
<td>1.70</td>
</tr>
<tr>
<td>100</td>
<td>2.00</td>
<td>1.90</td>
</tr>
</tbody>
</table>
Gravel Filters

- Gravel filters should not be less than 15 to 23 cm
- ½ thickness of Riprap layer is a good guideline
- Suggested gravel filter gradation equations are shown to the right

\[
\begin{align*}
\frac{d_{10}(\text{filter})}{d_{10}(\text{bank})} & < 40 \\
5 & < \frac{d_{15}(\text{filter})}{d_{15}(\text{bank})} < 40 \\
\frac{d_{5}(\text{filter})}{d_{5}(\text{bank})} & < 5
\end{align*}
\]
5. Bedload and Suspended Load

Incipient Motion
Muestreador US BL-84
Isokinetic Depth-integrating Sampler
Collapsible-bag sampler array

As used in:
Amazon
Orinoco
Mississippi
Run 19
Vanoni, 1946

Run 55
Einstein &
Chien, 1955

Run S-16

Hyper-conc.

Hyper-conc.

SEDIMENT RATING CURVES

Data Guy et al., 1966

Bedload
Mixed load
Suspended load

R = \frac{\nu}{\omega s}

\frac{h}{d} = 100

\frac{h}{d} = 1000

\frac{h}{d} = 10000

\frac{h}{d} = 100000

\frac{h}{d} = 1000000

\frac{h}{d} = 10000000

\frac{h}{d} = 100000000
6. Flow in Bends

- Thalweg
- Sedimentation
- Erosion
- Fine sediment in suspension
- Coarse sediment bedload
- Equilibrium
- Point bar
The Mississippi River flows at a rate of 4.9 ft/s, with a sand concentration of 838 ppm and a bed sediment size of 0.20 mm. The distance above the stream bed is 31,600 ft/s². The graph shows stationing across the section, with water surface measurements at various distances from the right and left banks.
THANK YOU for your Attention!